Biomedical Control Systems

Lecture#01

Text Books

- **Modern Control Engineering**, 5th Edition; Ogata.
- **Feedback & Control Systems**, 2nd edition; Schaum's outline, Joseph J, Allen R.
- **Control Systems Engineering**, 6th edition; Norman S. Nise.

Marks Distribution

- Theory exam : 80 marks
- Sessionals: 20 marks
  - Attendance- 10 marks
  - Class Test- 10 marks
- Practical: 50 marks
  - Practical test-15 marks
  - Practical viva-15 marks
  - Sessionals-20 marks

Course Outline

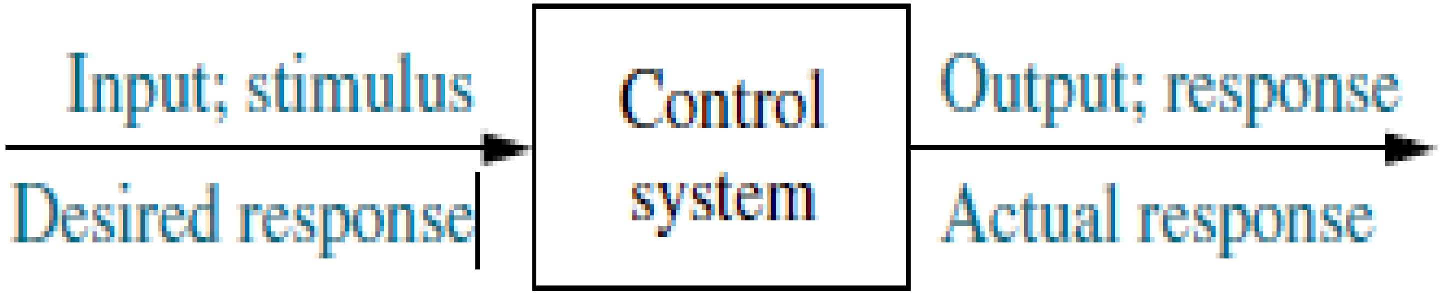
- Introduction to Control System, Basic elements in Control system.
- Open & Closed loop control system.
- Feedback & its effect, types of Feedback Control system.
- Differential equation representation of physical systems, transfer function.
- Mathematical modeling of different control system.
- Block diagram representation of systems, block diagram reduction techniques, signal flow graph.
- First-order system, step, ramp & impulse response analysis.
- Second-order system, step response analysis.
- Steady-state error, generalized error coefficient.
- Principle of PID compensation stability analysis.
- Stability of linear control systems, BIBO.
- Methods of determining stability- Routh Hurwitz criterion
- Root Locus method. **Sessional Test-I**
- Frequency response, frequency domain specifications of second order system.
- Correlation between time domain & frequency domain.
- Bode plot, stability analysis using Bode plot, gain & phase margin.
- Polar plot-Nyquist stability criterion.
- Concepts of state, state variables & state model.
- State model of linear system, state space representation using physical variables.
- Time-domain solution of state equation.
- Laplace Transform.
- Controllability & Observability.
- State-space representation of Discrete-time system. **Sessional Test-II**

Definition

- **System** – An interconnection of elements and devices for a desired purpose.
- **Control System** – An interconnection of components forming a system configuration that will provide a desired response.
- **Process** – The device, plant, or system under control. The input and output relationship represents the cause-and-effect relationship of the process.

Control System

- A control system consists of subsystems and processes (or plants) assembled for the purpose of obtaining a desired output with desired performance, given a specified input. Figure shows a control system in its simplest form, where the input represents a desired output.



CONTROL SYSTEM TERMINOLOGY

To discuss control systems, we must first define several key terms.

- ***Input-***Stimulus or excitation applied to a control system from an external source, usually in order to produce a specified response from the system.
- ***Output-*** The actual response obtained from the system. It may or may not be equal to the specified response implied by the input.
- ***Feedback-*** That portion of the output of a system that is returned to modify the input and thus serve as a performance monitor for the system.
- ***Error-*** The difference between the input stimulus and the output response. Specifically, it is the difference between the input and the feedback.

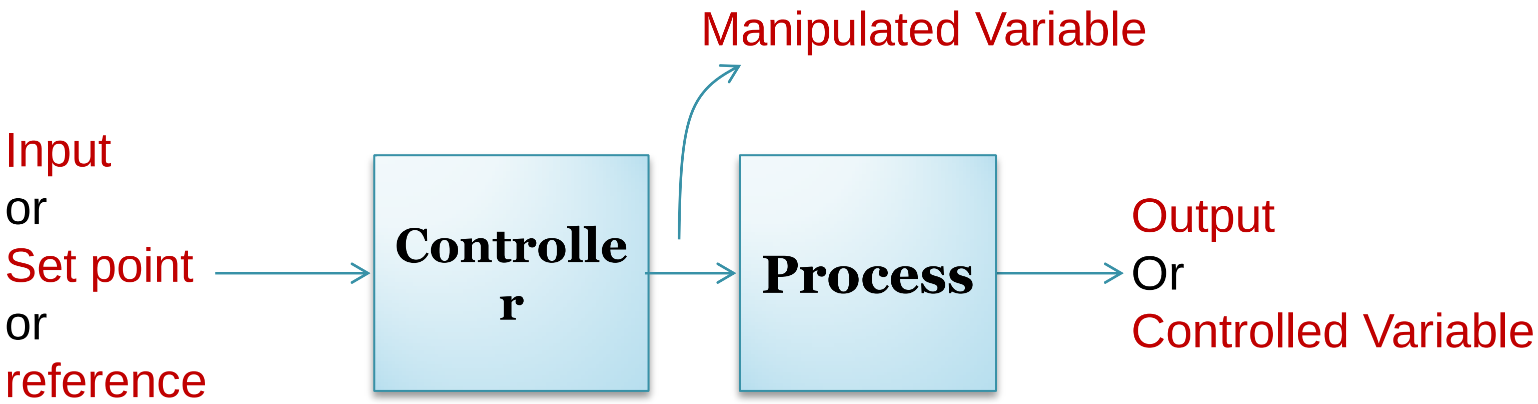
Definitions

Controlled Variable– It is the quantity or condition that is measured and Controlled. Normally *controlled variable* is the output of the control system.

Manipulated Variable– It is the quantity of the condition that is varied by the controller so as to affect the value of *controlled variable*.

Control – Control means measuring the value of *controlled variable* of the system and applying the *manipulated variable* to the system to correct or limit the deviation of the measured value from a desired value.

Definitions



Disturbances– A disturbance is a signal that tends to adversely affect the value of the system. It is an unwanted input of the system.

- If a disturbance is generated within the system, it is called *internal disturbance*. While an *external disturbance* is generated outside the system.

Example

- A very simple example of a feedback control system is the **thermostat**. The *input* is the temperature that is initially set into the device.
- Comparison is then made between the input and the temperature of the outside world.
- If the two are different, an *error* results and an *output* is produced that activates a heating or cooling device.
- The comparator within the thermostat continually samples the ambient temperature, i.e., the *feedback*, until the *error* is zero; the *output* then turns off the heating or cooling device.

Example

- **The seemingly simple act of *pointing at an object with a finger requires a biological control system*** consisting chiefly of the eyes, the **arm, hand and finger, and the brain. The input is the precise direction of the** object (moving or not) with respect to some reference, and the output is the actual pointed direction with respect to the same reference.
- **A part of the human temperature control system is the *perspiration system. When the temperature*** of the air exterior to the skin becomes too high the sweat glands secrete heavily, inducing cooling of the skin by evaporation. Secretions are reduced when the desired cooling effect is achieved, or when the air temperature falls sufficiently. The input to this system may be "normal" or comfortable skin temperature, a "setpoint," or the air temperature, a physical variable. The output is the actual skin temperature.

Advantages of Control Systems

We build control systems for four primary reasons:

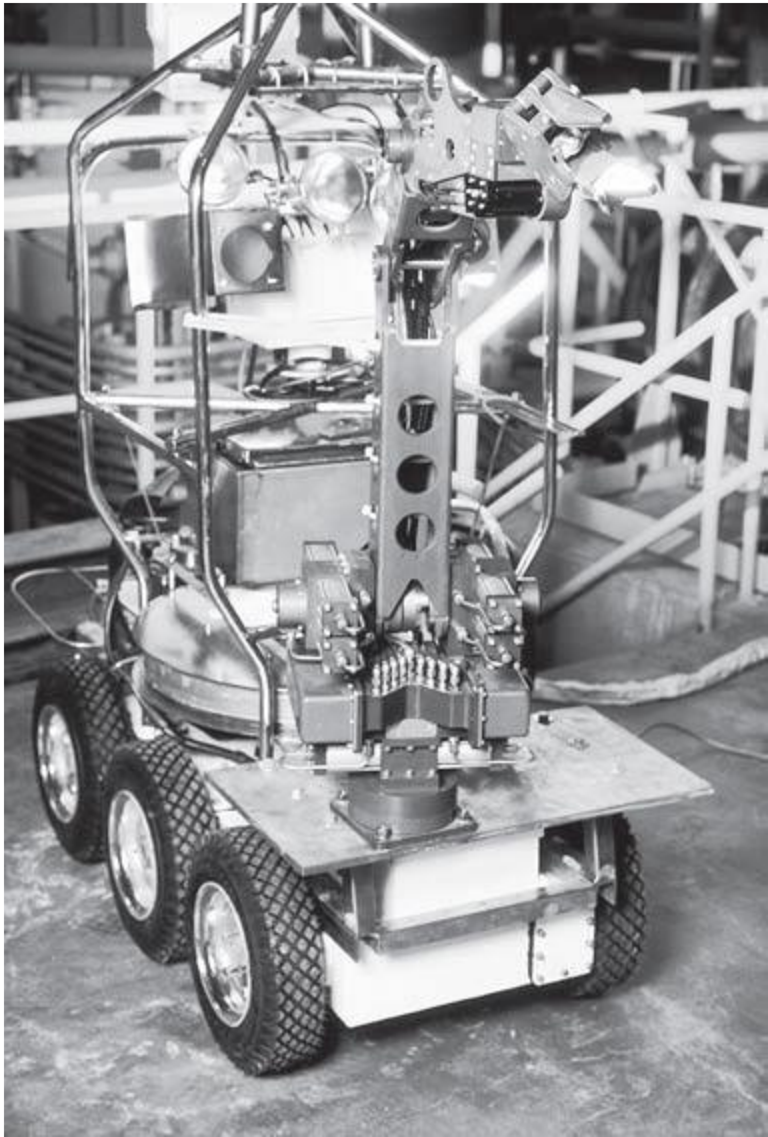
1. Power amplification
2. Remote control
3. Convenience of input form
4. Compensation for disturbances

- For example, a radar antenna, positioned by the low-power rotation of a knob at the input, requires a large amount of power for its output rotation. A control system can produce the needed power amplification, or power gain.

Example

- Robots designed by control system principles can compensate for human disabilities. Control systems are also useful in remote or dangerous locations. For example, a remote-controlled robot arm can be used to pick up material in a radioactive environment.

Figure 1.4 shows a robot arm designed to work in contaminated environments.



History

18th Century James Watt's centrifugal governor for the speed control of a steam engine.

1920s Minorsky worked on automatic controllers for steering ships.

1930s Nyquist developed a method for analyzing the stability of controlled systems

1940s Frequency response methods made it possible to design linear closed-loop control systems

1950s Root-locus method due to Evans was fully developed

1960s State space methods, optimal control, adaptive control and

1980s Learning controls are begun to investigated and developed.

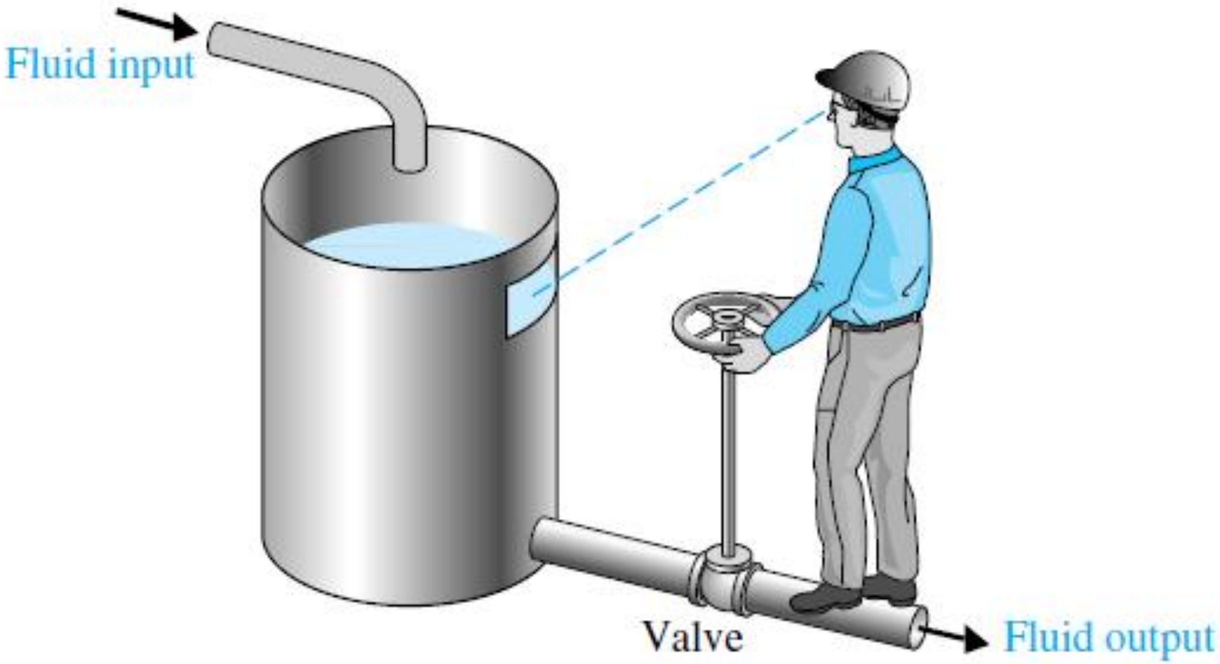
Present and on-going research fields. Recent application of modern control theory includes such non-engineering systems such as biological, biomedical, economic and socio-economic systems

???????????????????????????????????

Assignment

- Find out the latest research going on in the field of control engineering related to biomedical/biomedicine/medical field.

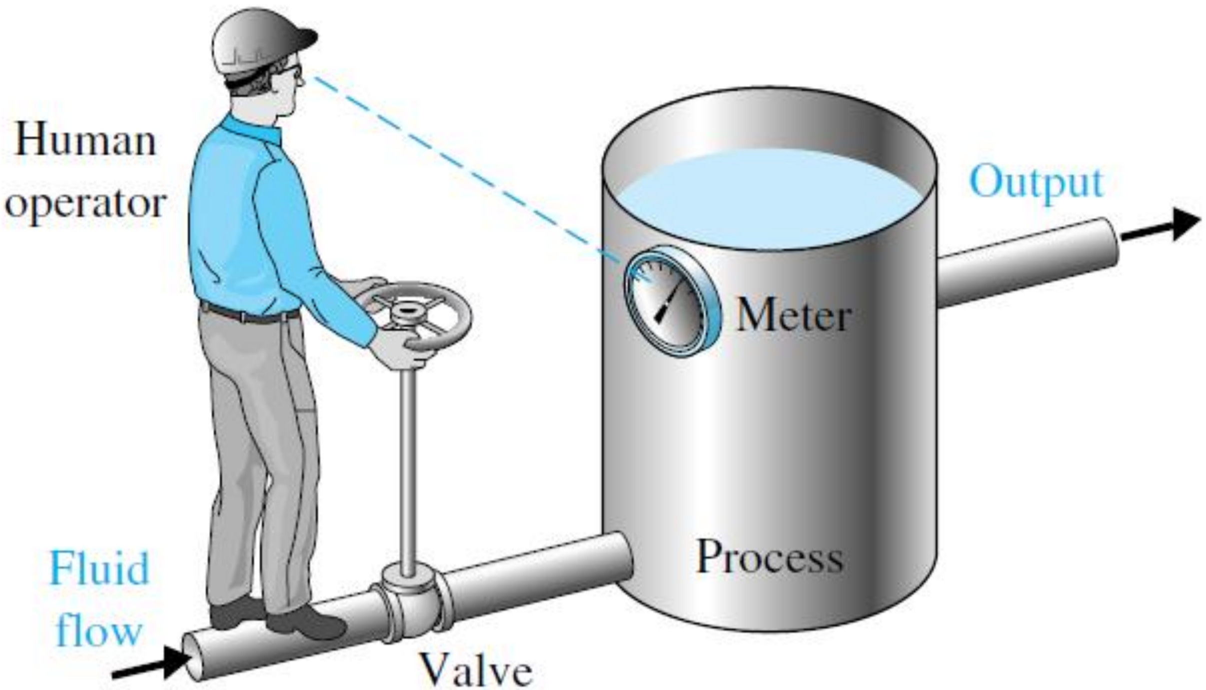
Examples of Control Systems



A manual control system for regulating the level of fluid in a tank by adjusting the output valve. The operator views the level of fluid through a port in the side of the tank.

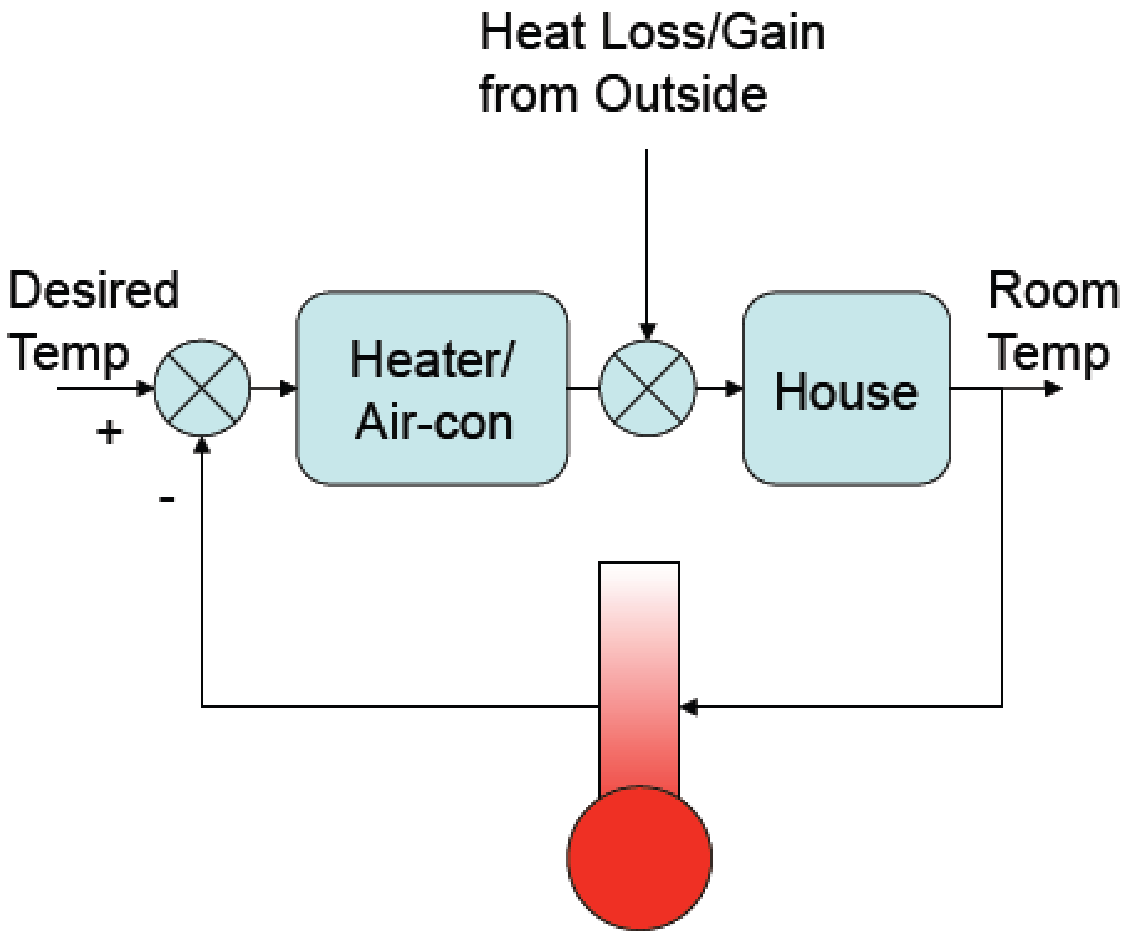
Examples of Control Systems

Fluid-flow control

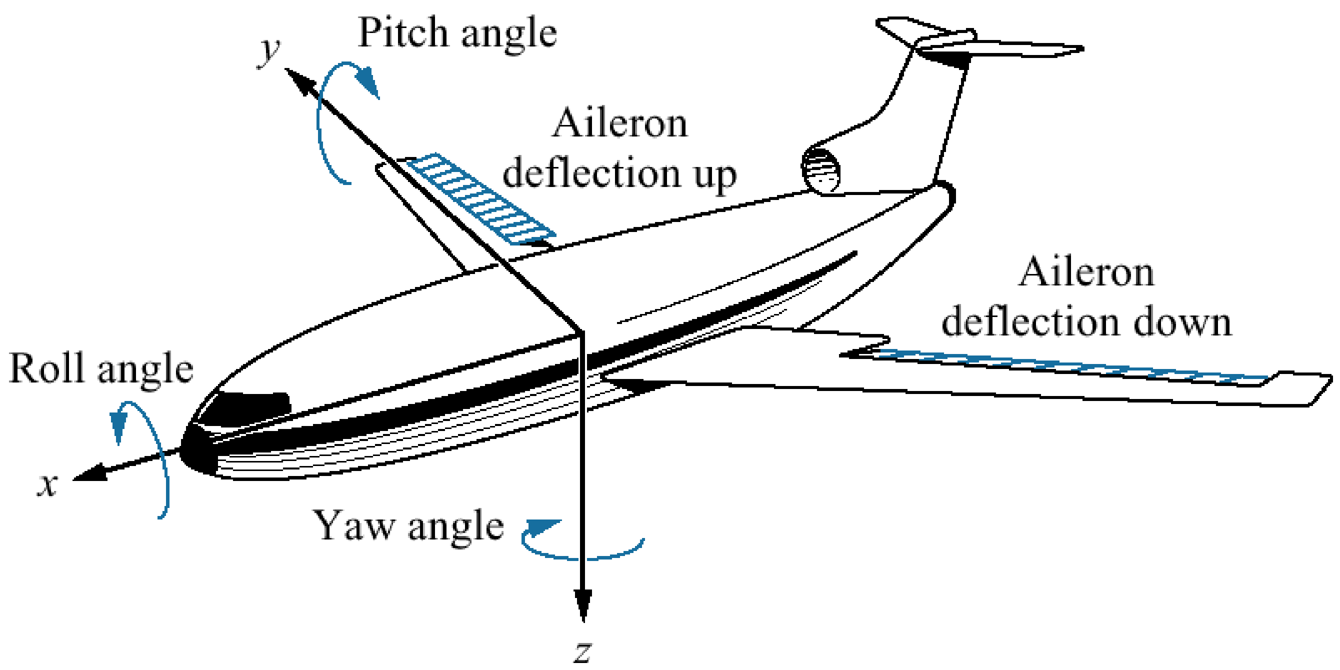


Examples of Control Systems

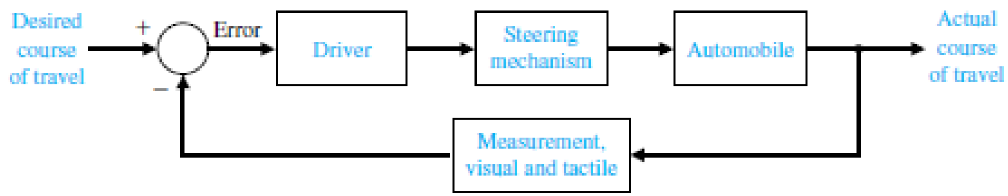
Room Temperature Control



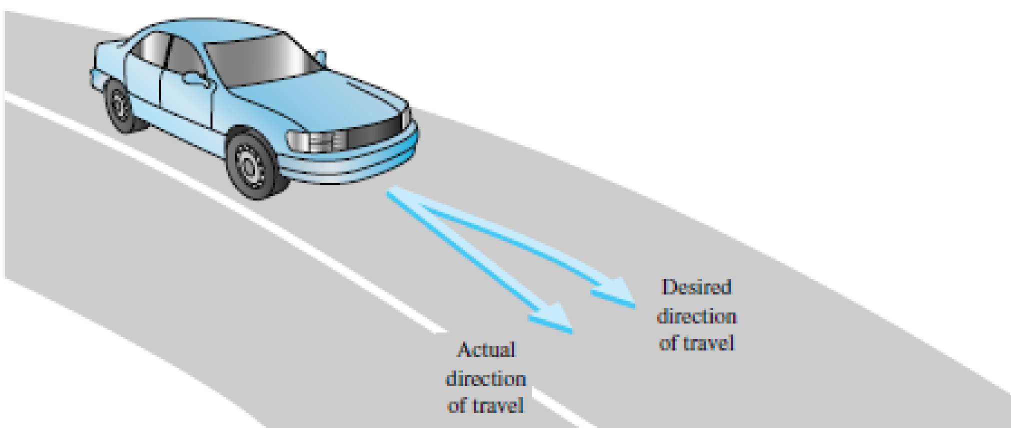
Examples of Modern Control Systems



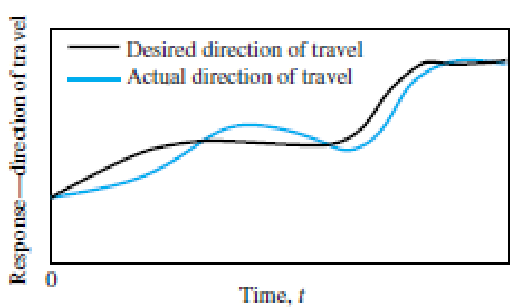
Examples of Modern Control Systems



(a)



(b)



(c)

(a) Automobile steering control system.

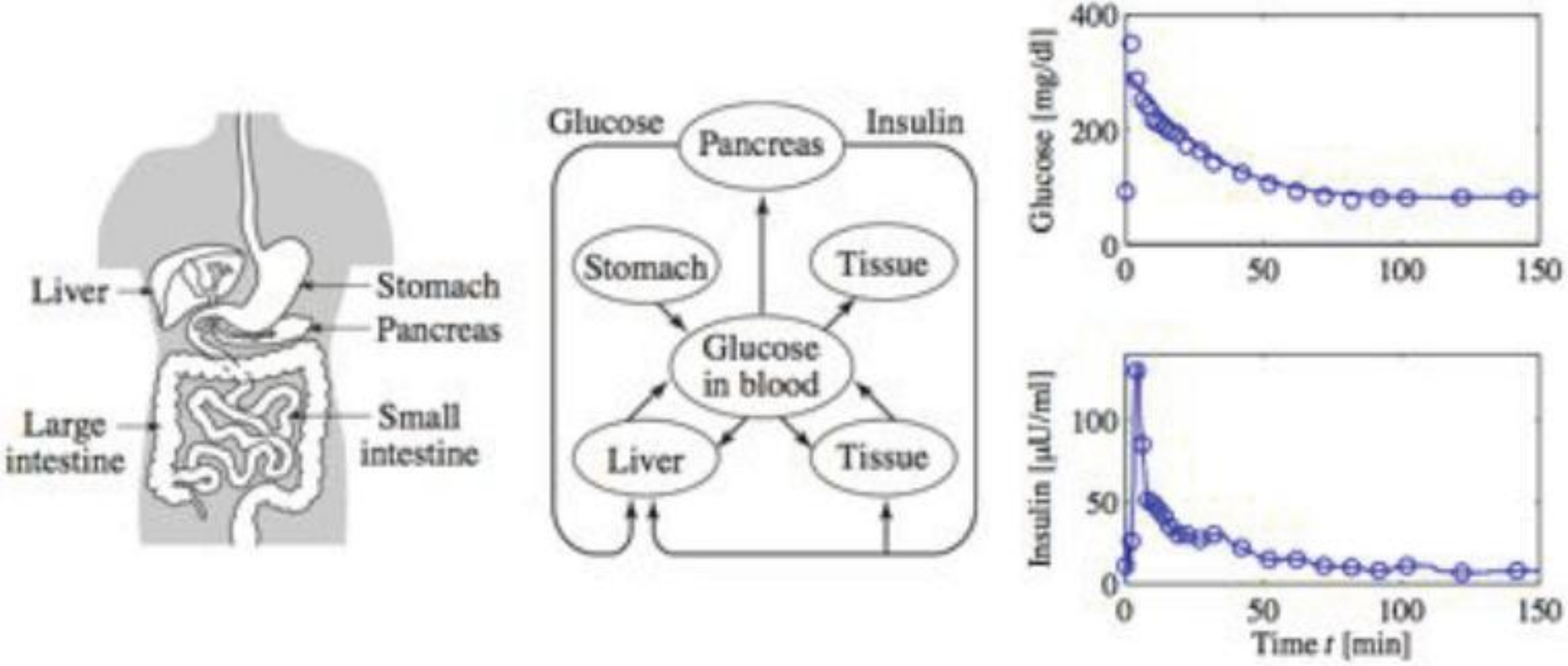
(b) The driver uses the difference between the actual and the desired direction of travel

to generate a controlled adjustment of the steering wheel.

(c) Typical direction-of-travel response.

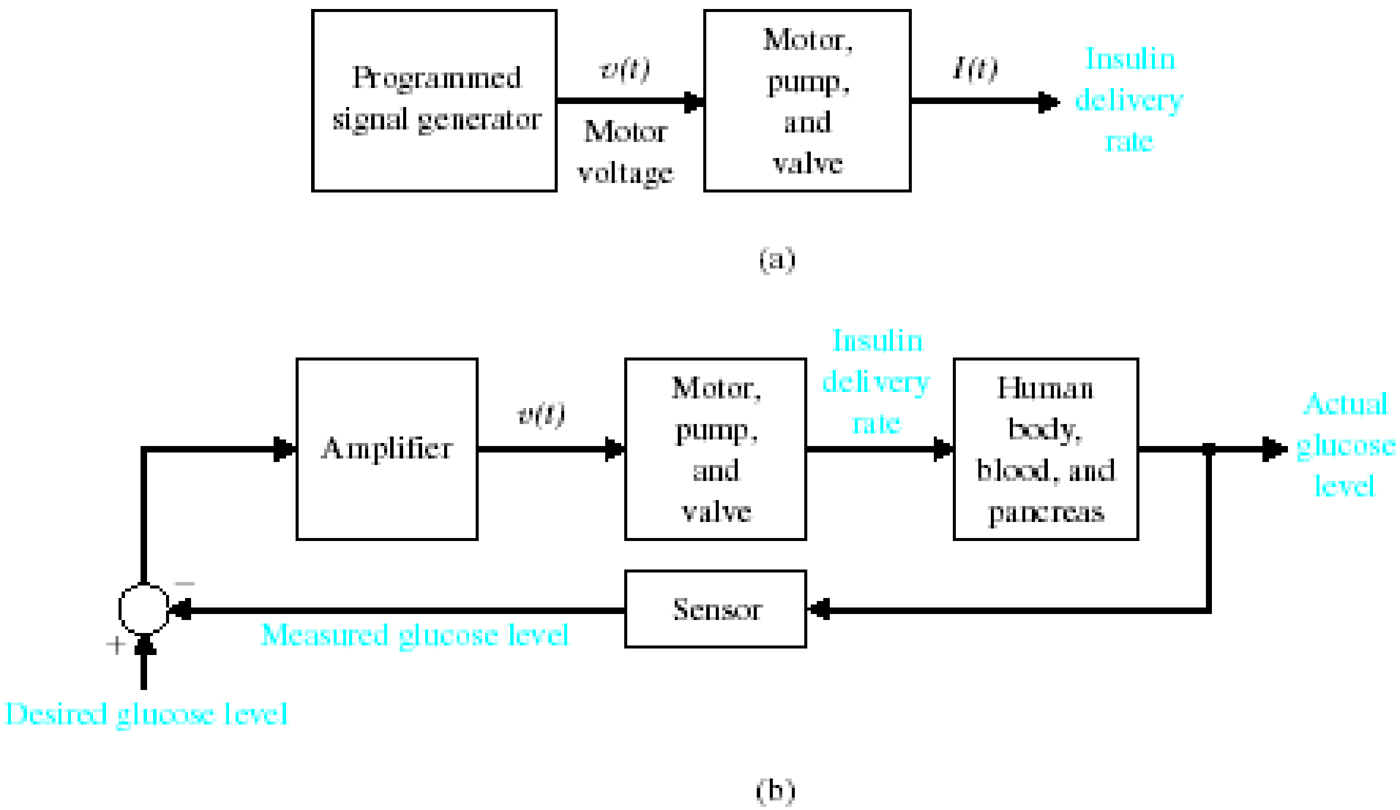
Examples of Control Systems

Insulin/Glucose Dynamics



Examples of Modern Control Systems

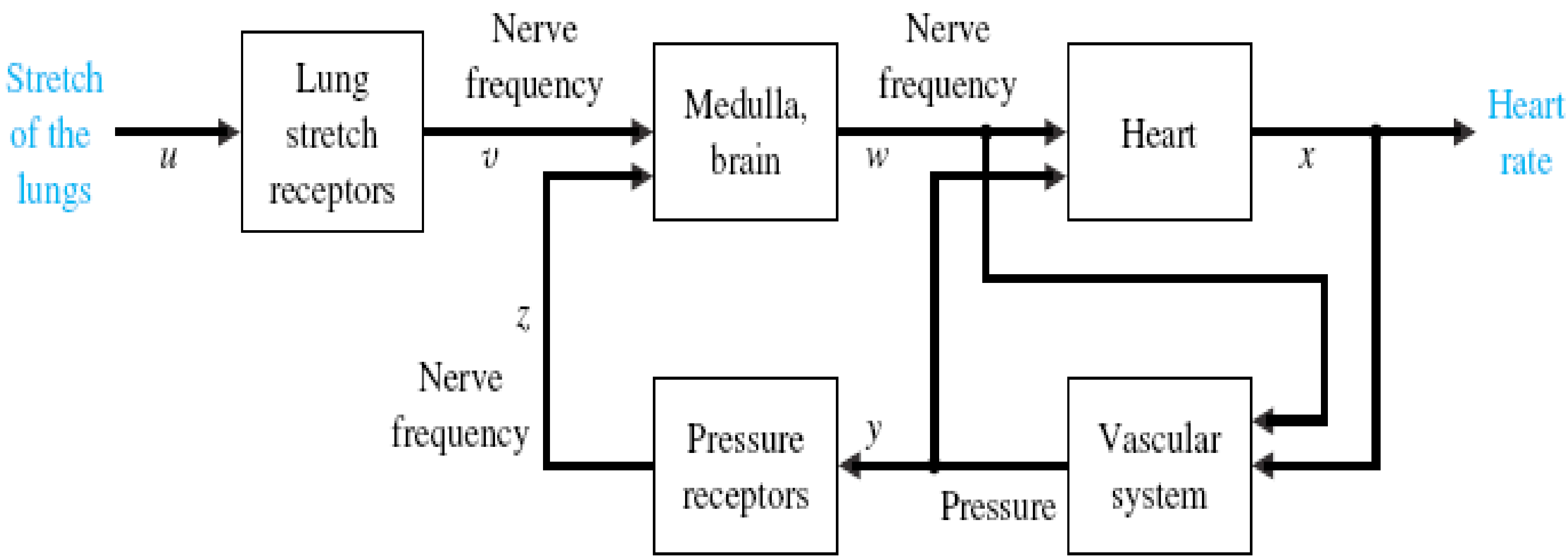
Open-loop & Closed-loop Models of Blood Glucose Control System



(a) Open-loop (without feedback) control and
(b) closed-loop control of blood glucose.

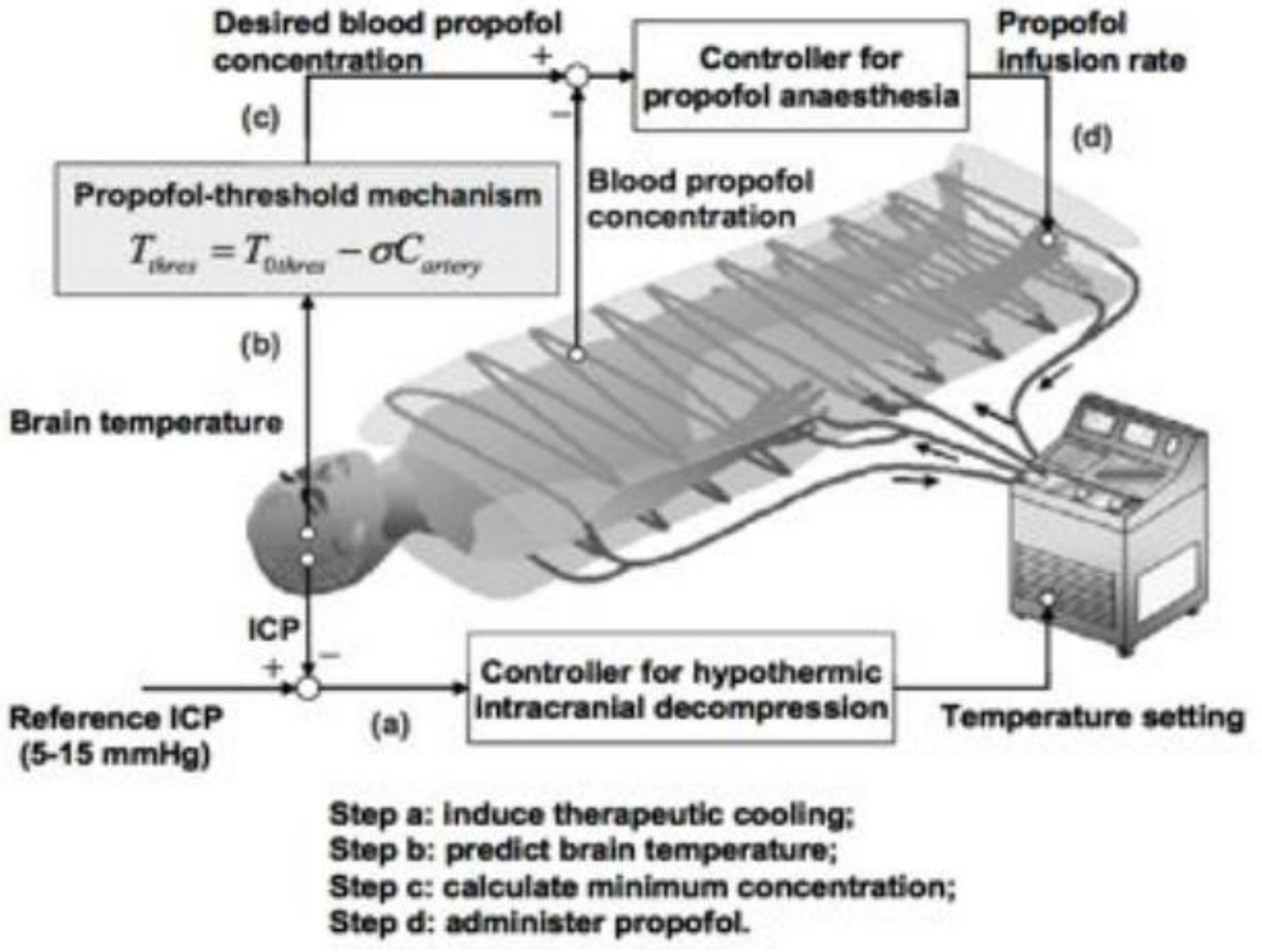
Examples of Control Systems

A Model of Heart Rate Control System



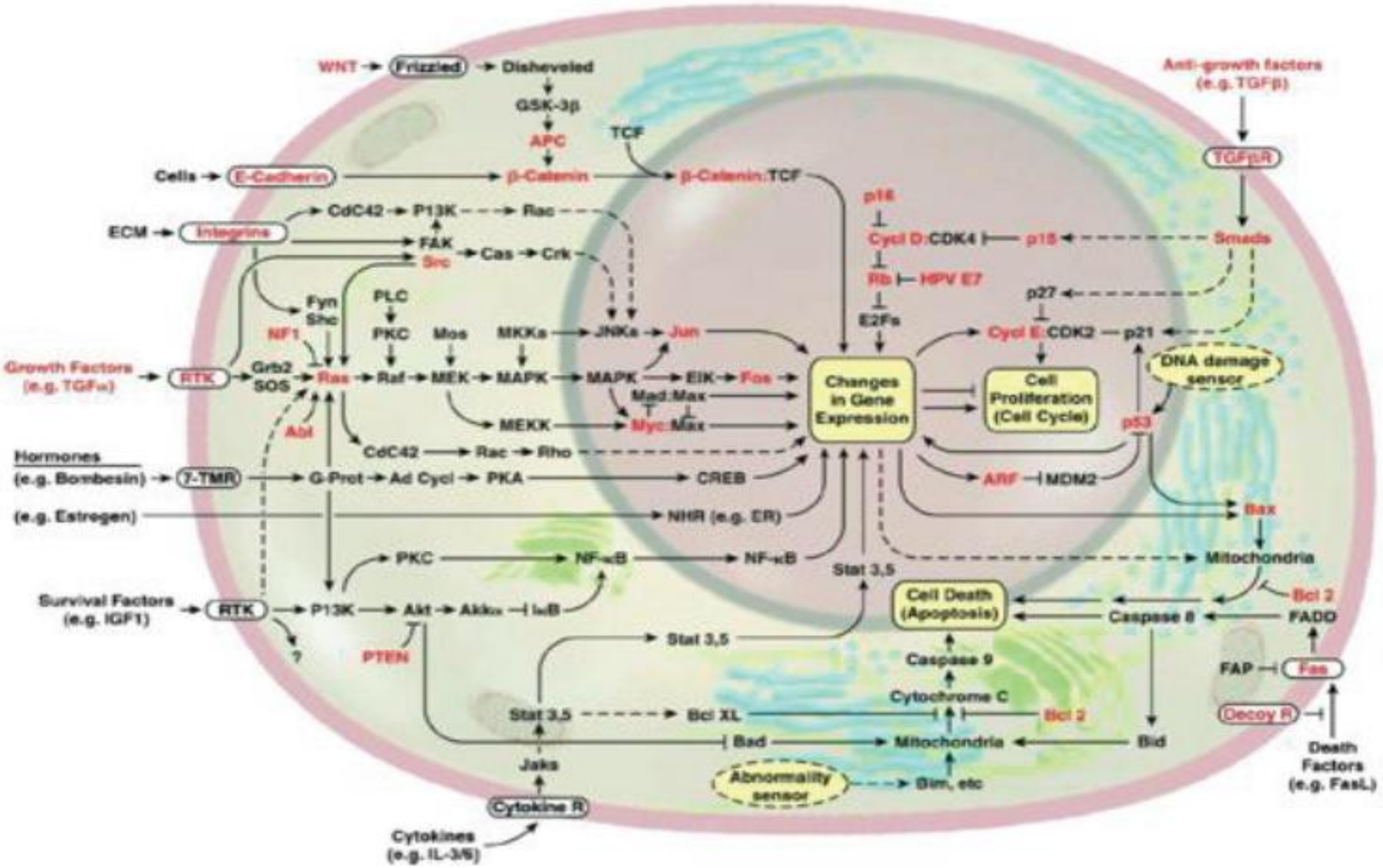
Examples of Modern Control Systems

Control of Anaesthesia

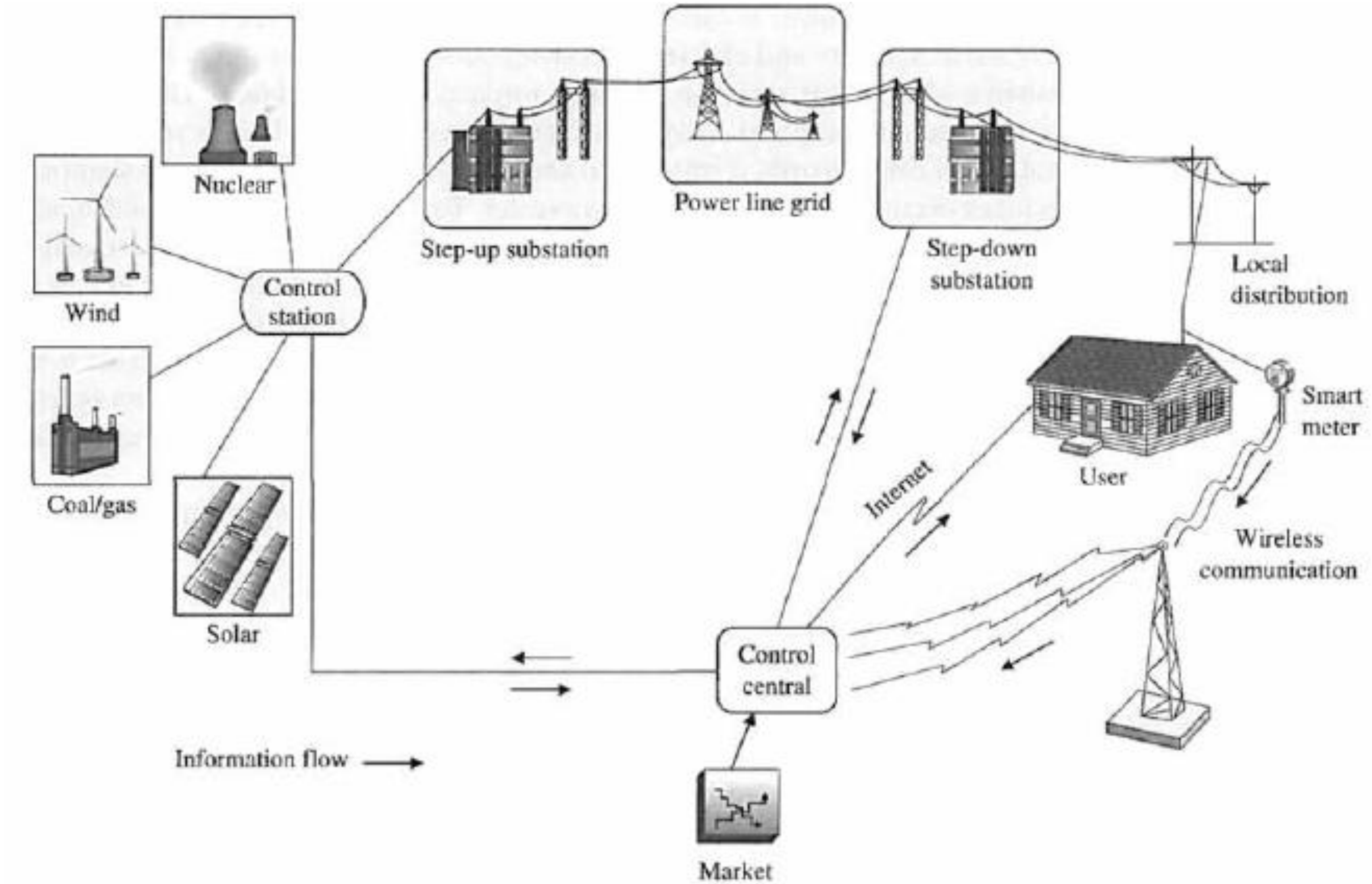


Examples of Control Systems

Mammal cell-growth control



Examples of Control Systems



Smart grids are distribution networks that measure and control usage.